International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 10 Oct. 2022, pp: 629-633 www.ijaem.net ISSN: 2395-5252

Evaluating Compressive strength of Ire Clay Geopolymer Concrete Cured at roomTemperature

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Date of Submission: 05-10-2022 Date of Acceptance: 14-10-2022

ABSTRACT
This study investigates the potential of abundantly available geological elements at Ire-Ekiti as source materials for geopolymer concrete, with the aim of obviating energy requirements that are commonly acknowledged to be crucial for geopolymer manufacture. Ire Clay was obtained, air-dried, then calcined for two hours at 750°F in a furnace. Pulverized calcined clay was utilized as the raw material for a geopolymer gel containing 12M of NaOH and Na_2SiO3. The ratio of NaOH to Na_2SiO_3 is 2:5. As economical fillers, river sand and 12mm aggregate size granite were incorporated into the geopolymer concrete mix ratio of 1:2:3. Mixtures of specimens were cured at room temperature for 7, 14, and 28 days for various maturities. At normal temperature, the compressive strength of Ire Clay geopolymer concrete rises with age for curing, with a 38% increase in compressive strength from 7 to 28 days.

I. INTRODUCTION

Due to their low cost, outstanding mechanical and physical qualities, minimal energy consumption, and reduced "green house emissions" during production, geopolymers have garnered great interest. As Geopolymer concretes do not contain Portland cement and the powder binder is often an industrial waste or little processed natural material, they can be promoted as environmentally benign and have lower carbon dioxide emissions than conventional concrete.

As a result of its diverse mechanical qualities, improved performance, adaptability, simple application, and cost-effectiveness, cement production on a massive scale is encouraged by the global demand for concrete as a construction material. According to the 2018 International Cement Review Research Report, the worldwide cement demand is anticipated to exceed 4.216 billion tons (2017). Cement manufacture consumes an estimated 94.76106 Joules/ton of energy per year (Davidovits, 1994), resulting in an estimated 5 to 7% of the overall output of carbon dioxide (Mehta, 2001), which is considered a significant factor in the acceleration of global warming. Increasing industrialisation results in the emission of pozzolanic waste byproducts such as fly ash, rice husk ash, and pulverized granulated blast furnace slags. The disposal and management of waste materials is a global challenge. The international earth summits also expressed concern over the growth in greenhouse gas emissions (Malhotra, 1999), which prompted the cement industry to convert from Portland cement to a greener alternative binder with acceptable structural qualities.

Recently, geopolymer composites have emerged as an eco-friendly alternative to conventional cementitious materials. They are cost-effective, environmentally friendly, and need a tiny amount of energy to produce. In addition, they offer excellent compressive strength, durability, and thermal qualities, as they are very resistant to flame and heat. Alkaline liquid reacts with a source material that is rich in silica and alumina to form geopolymer concrete. Davidovits (1988) postulated that an alkaline liquid may be used to react with silicon (Si) and aluminum (Al) in a geological source material or in by-product materials like fly ash and rice husk ash to generate binders. Because the chemical reaction occurring in this instance is a polymerization, he invented the name "Geopolymer" to refer to these binders. Geopolymer concrete is concrete that is produced without the use of Portland cement. Geopolymer concrete is the subject of intensive research and has the potential to replace Portland cement concrete. The focus of research is changing from chemistry to engineering applications and the manufacturing of geopolymer concrete for commercial use.

The choice of raw materials for the production of geopolymers is influenced by factors such as availability, pricing, kind of application,

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and unique end-user demand. Alkaline liquids are often derived from soluble sodium or potassium-based alkali metals. The most prevalent alkaline liquid utilized in geo-polymerisation is a mixture of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. Calcium at excessive concentrations can interfere with the polymerization process and affect the microstructure, according to Gourley and Johnson (2005). The kind and composition of the raw materials, alkaline activators, and curing conditions have been recognized as the most influential aspects of geopolymerization. A crucial component in limiting the leaching of alumina and silica from raw materials is the alkali concentration. The activation of silicates enhances the solubility of raw materials and generates advantageous mechanical characteristics. For different raw materials, the optimal alkaline content, ratio of activator liquid to raw material mass, and sodium silicate/sodium hydroxide solution ratio would vary. Different curing conditions are recorded for various constituents and activators (Bagchi et al., 2018). This research investigates the compressive strength property of Ire Clay geopolymer concrete considering ire clay as a geologically derived material and determining its appropriateness for geopolymer manufacturing cured at room temperature with reduced energy input throughout the production process.

II. MATERIALS AND METHOD

1.1. Material

Calcined clay (CC) was created by heating Ire clay for two hours at 750 °C in a furnace. As advised by Davidovits, J., sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) were chosen as activators since they are the most prevalent and manageable alkali materials (2013). The relevant 12M molar solutions of 98% pure sodium hydroxide were produced.

This project utilized locally available fine aggregates (river sand). It was subjected to a physical laboratory test known as particle size distribution, also known as sieve analysis, because it appeared to be devoid of debris and clay. Fine aggregate is an indispensable component of concrete made from sand or crushed stone. The quality of the fine aggregate density has a substantial impact on the hardened qualities of cement concrete. If fine aggregate is selected based on grading zone, particle shape and surface texture, abrasion and skid resistance, and absorption and surface moisture, the cement concrete or mortar mixture can be made more durable, stronger, and more cost-effective.

Coarse aggregate is the component of geopolymer concrete that consists of the larger stones incorporated inside the mixture. It was gathered from a quarry site in the Nigerian state of Ekiti and has an aggregate size of 12mm, passing through sieve sizes of 12mm to 4mm. It was also subjected to a particle size distribution test in the laboratory. Aggregate retained on each sieve ranging from 12 mm to 4 mm in size when employed.

Plate 3.3a, Sodium Silicate (Na_2SiO_3), and Plate 3.3b, Sodium Hydroxide, depict the alkaline activators utilized in the execution of this project (NaOH).

Since the molecular weight of Sodium Hydroxide is 40, 12 Molar solution was utilized, and in order to make 12molar solution, 480 grams of sodium hydroxide were dissolved in 1000 milliliters of water (12 x 40 = 480). One liter of Sodium Silicate (Na_2SiO_3) was employed to produce 480 grams of Sodium Hydroxide (NaOH).



Plate3.2a: Sodium Silicate **Plate3.2b:**Sodium Hydroxide **Plate3.2c**:Alkaline

Alkaline was diluted with distilled water to the required molarity.

1.2. Test on Materials

This involves the placement of a pre-weighed mass of aggregates (i.e. coarse or fine) into a sieve shaker for 15 minutes. This is done in order to determine the percentages of aggregates retained on each sieve after the shaking and from the result; the percentage passing for each sieve is calculated. This test was carried out in the Civil Engineering soil laboratory, The Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria.

Specific gravity and chemical analysis test were conducted on calcinated ire clay

1.3. Preparation Of The Specimen

The recommended mix ratio of 1:2:3 geopolymer concrete by mass, in which geopolymer gel is one part, fine aggregate is two parts, and coarse aggregate is three parts.Three test samples were cast for varying maturities of 7, 14, and 28 days. 50*50*50 mm3 was cured at room temperature to the specified degree of maturity.

1.4. Test on Specimen

Geopolymer concrete was tested for its compressive strength at the AfeBabalola University Department of Civil Engineering Laboratory. The compressive strength test was conducted utilizing a wizard basic compression test machine that was operated electronically. The test specimens were positioned in the hydraulic testing frame and a force was applied until the specimens broke. The prism halves were centered with respect to the machine's plates to within 0.5 mm and longitudinally so that the end face of the prism overhangs the plates by approximately 10 mm. The greatest force exerted and specimen dimensions were then recorded, and the specimen's compressive strength was computed.

III. RESULTS AND DISCUSSION

1.5. Physical Properties and Chemical Composition

Physical Properties

The source materials were subjected to several physical tests, which are detailed in the table below. All of the tests were conducted in the laboratory for soil mechanics at Federal polytechnic Ado-Ekiti in the state of Ekiti.

Table 3.1: Physical properties of geopolymer base material

Properties	**Ire-Clay**
Specific gravity	2.57
Grain size	-
Colour	Reddish brown

1.6. Chemical Composition

Clay is a good source material for geopolymer gel binder in geopolymer concrete based on the pioneering geopolymer research of Davidotis (1978). The percentage of various oxides in the source materials and agro-waste is shown in the table 3.2 below.

Table 3.2: Chemical composition of geopolymer base material

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	P_2O_5	K_2O	MgO	Na_2O	MnO	CuO	LOI
Ire Kaolin	58.96	19.85	3.31	0.36	0.11	0.23	0.38	1.91	0.01	0.21	11.26

3.3 Sieve Analysis

3.3.1. Sieve Analysis for Fine Aggregate

Figure 3.1 demonstrates the outcome of the sand grain analysis. The distribution curve for sand particles indicates that the aggregate meets the BS 882 minimum and maximum grading requirements for natural aggregates (1992).

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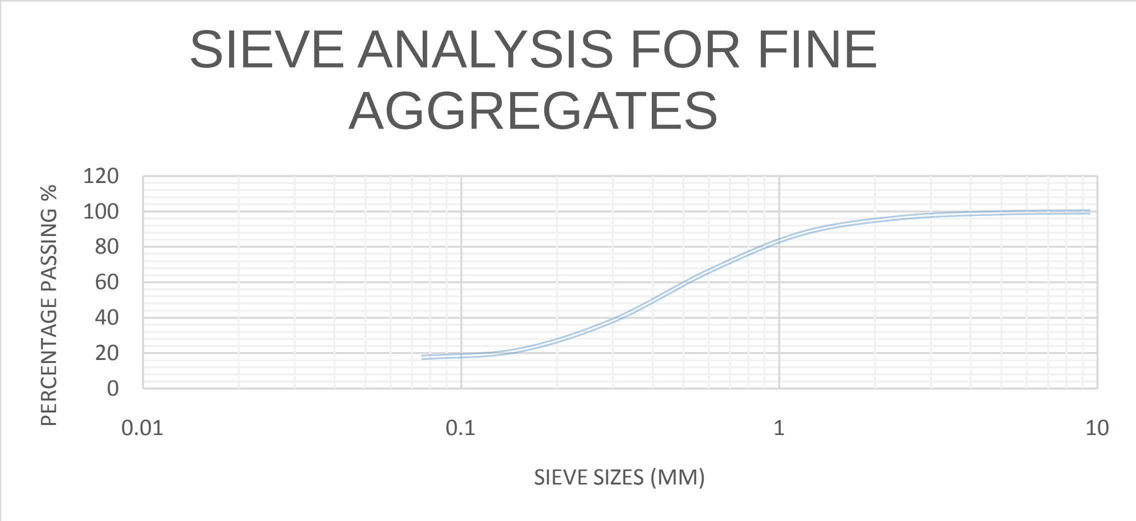

FIG3.1: Sieve analysis Curve

3.3.2 Sieve Analysis for Coarse Aggregate

The outcome of the analysis of gravel is indicated in The table below displays the various sieve sizes through which gravel passes when a mechanical shaking equipment is used.

It displays the gravel retained, as well as the percentages retained and passing. To get the percentage of gravel maintained, divide the amount of gravel retained by the total mass of gravel and multiply by 100.

Table 4.3b: Sieve analysis for coarse aggregates.

Sieve size	Weight retained (g)	Percentage retained (%)	Percentage passing (%)
12.5	296.8	29.68	70.32
11.2	118.2	11.82	58.5
9.5	159.5	15.95	42.55
8	156.2	15.62	26.93
6.3	150.4	15.04	11.89
4	107.8	10.78	1.11
Pan	10.4	1.04	0.07

3.4. Compressive Strength

In seven days, Ire clay Geopolymer Concrete trial samples attained a compressive strength of 1.71N/mm^2 in a compressive strength test. The compressive strength of geopolymer concrete cured at room temperature rises with age to an average value of 2.86N/mm^2 after fourteen days and 2.89N/mm^2 after twenty-eight days. In terms of strength gain with cure maturity, the behavior of Ire clay geopolymer concrete cured at room temperature is equal to that of cement concrete. Despite this, the degree of the strength improvement for equivalent ages of geopolymer concrete cured at room temperature is much less than the expected compressive strength of cement concrete of same mix and curing conditions.

The compressive strength of geopolymer concrete derived from Ire clay is shown in Table 4.4.

Table 4.4: Compressive strength of sample

Test Trials	7 days	14 days	28 days
1	1.69	2.86	2.87
2	1.73	2.88	2.90
3	1.71	2.84	2.88
Average (N/mm^2)	1.71	2.86	2.89

IV. CONCLUSIONS

This study demonstrates that the Ire Clay deposit is a feasible raw material for the manufacturing of geopolymer concrete at room temperature, with increasing compressive strength with age. The development of Ire clay geopolymer concrete's compressive strength identifies specimens as candidates for additional research on optimizing compressive strength for processing and additives.

Adjusting the processing and activator concentrations of Sodium hydroxide NaOH and its ratio to Sodium silicate NaSi3 for the activation of calcined Ire Clay-derived materials is anticipated to result in an improvement in performance. Additives may be explored for improving Ire Clay geopolymer concrete positively.

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